

# **MISSION ARCHITECTURE IMPACTS ON VENUS SURFACE PROBE LIFETIME**

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# Mission Scenario

- **Total Probe Mass**
  - The mission uses a carrier vehicle, which will target the probe (pressure vessel and entry/descent/ deployment hardware) and then separate, flying past Venus and being discarded. 1200 kg maximum entry mass, with maximum of 1000 kg delivered to or near the surface.
- **Systems**
  - Pressure Vessel and Passive Thermal Control System (phase change material)
  - Instruments: Descent/Surface Imager, GC/MS, X-ray Florescence Spectrometer, Rb-Sr laser ablation/resonance ionization/mass spectrometer for age dating, Pressure/Temperature sensors. Sample acquisition (Drill) and transfer hardware
  - Telecom: 2 Kbps from the lander to Earth, downlink implemented with 80 W RF TWTA's combined for ~150 W RF output power for S-band comm
  - Avionics: CDS, power conditioning, micro-gyro
  - Power: Primary Battery and power switching
- **Nominal Mission Scenario**
  - The descent/surface imager is the main driver for data volume. Once the images have been captured and returned to Earth (along with descent pressure and temperature data), the cycle of drilling cores and processing them will commence. Each 10 cm core is estimated to require 1 hour to drill. Processing of each sample will take approximately 6 and one half hours.

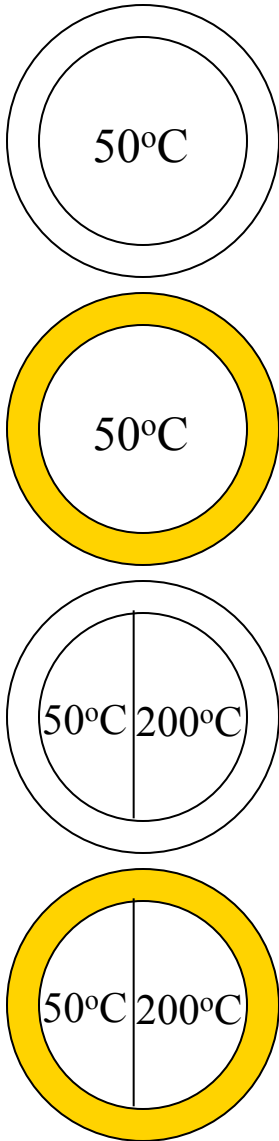


# Mission Power Consumption per 8 hr core sampling cycle

| Mission Mode        | 1.<br>Descent | 2. Return of<br>Descent/Surface<br>images | 3. Core<br>Drilling<br>(per<br>sample) | 4. Core<br>Analysis<br>(per<br>sample) | 5.<br>Return<br>of<br>sample<br>data (per<br>sample) | Total for<br>modes 3-<br>5 = 8 hr<br>core<br>sampling<br>cycle |
|---------------------|---------------|---|--|--|--|--|
| Duration (hrs)      | 1             | 10  | 1                                      | 6.5                                    | 0.5  | 8  |
| Power Usage (w)     |               |   |  |  |  |  |
| Instruments         | 3.5           | 3.5                                       | 3.5                                    | 26                                     | 3.5  |  |
| Drill               | 0             | 0   | 151                                    | 0                                      | 0  |  |
| Power               | 21            | 20  | 57                                     | 2.4                                    | 20   |  |
| Telecom             | 150           | 280                                       | 0                                      | 0                                      | 280  |  |
| C&DH                | 7.5           | 7.5                                       | 7.5                                    | 7.5                                    | 7.5  |  |
| <b>TOTAL (w)</b>    | <b>182</b>    | <b>311</b>                                | <b>219</b>                             | <b>35.9</b>                            | <b>311</b>   |  |
| <b>TOTAL (whrs)</b> | <b>182</b>    | <b>3110</b>                               | <b>219</b>                             | <b>233.35</b>                          | <b>155.5</b>   | <b>607.85</b>  |



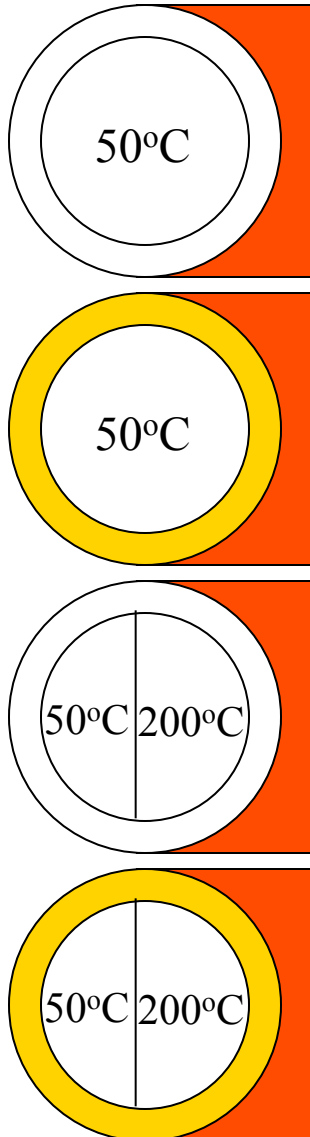
# Basic Architectures



- **1-** Baseline: Pressure Vessel at 50°C with State of the Art thermal management.
  - Use current technology.
  - All the following cases will be compared to this case and the benefits to mission will be assessed.
- **2-** Pressure Vessel at 50°C with Advanced thermal management technology.
  - Use technologies that have a realistic chance of being available in 5 years.
- **3a-** Pressure Vessel with cold(50°C)/hot(200°C) compartments.
  - Determine subsystems that can be in the hot side.
  - Use same State of the Art thermal management as in case 1.
- **3b-** Pressure Vessel with cold(50°C)/hot(200°C) compartments.
  - Determine subsystems that can be in the hot side.
  - Use same Advanced thermal management as in case 2.



# Basic Architectures (cont' d)

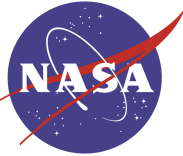


- **4a-** Pressure Vessel at 50°C with components outside of the pressure vessel.
  - Use same State of the Art thermal management as in case 1.
  - Candidate 500°C components include batteries, selected telecom, avionics, and sensors
- **4b-** Pressure Vessel at 50°C with components outside of the pressure vessel.
  - Use same Advanced thermal management as in case 2.
- **5a-** Pressure Vessel with cold(50°C)/hot(200°C) compartments with components outside the vessel. Same as in case 4.
  - Use same State of the Art thermal management as in case 1.
- **5b-** Pressure Vessel with cold(50°C)/hot(200°C) compartments with components outside the vessel. Same as in case 4.
  - Use same Advanced thermal management as in case 2.



# **Analysis Approach**

- **Calculate total power consumed as a function of mission life and use to size primary battery**
- **Calculate total power dissipated as a function of mission life and use to size thermal system**
- **These change depending on configuration (50 C, 50 + 200 C, 50 +500 C) and are not the same**
  - **Power radiated by telecom does not affect thermal load**
  - **Anything consuming power at 500 C does not affect thermal load**
- **Add up the masses (including constant pressure vessel and component masses) and plot as a function of mission life**



# **High Temperature Venus Mission Benefit Analysis Assumptions**



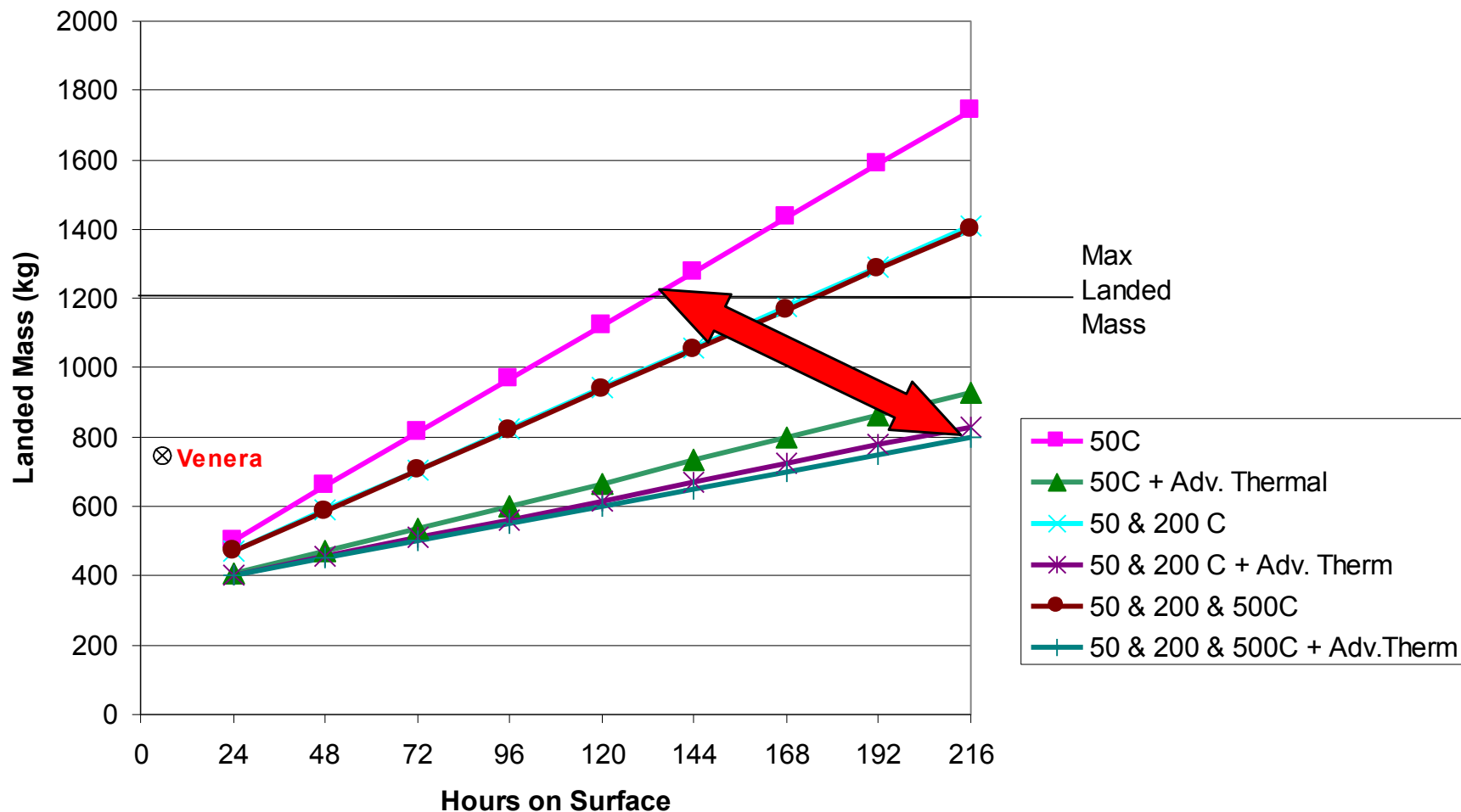
- **4 configurations evaluated (combinations of 50C, 200C, & 500C)**
- **State of the art Thermal Phase Change Material assumed**
  - Advanced technology TPCM also evaluated
- **State of the art Avionics and Telecom**
  - Existing high temperature components used for 200C configurations
  - Results of advanced technology Avionics and Telecom in process
- **Batteries**
  - **Li/SOCl<sub>2</sub> primary cell (state of the art for 50 C battery: TRL 9)**
    - Cell level specific energy: 275 Wh/kg
    - Projected cell level energy density: 850 Wh/l
  - **lithium-carbon poly monofluoride primary cell (TRL 1-2)**
    - Projected cell level specific energy: 550 Wh/kg
    - Projected cell level energy density: 1000 Wh/l
  - **Lithium-Venusian atmospheric fuel cell (TRL <1)**
    - Projected cell level specific energy: 6000 Wh/kg (12,500 Wh/kg theoretical)
    - Projected cell level energy density: 5000 Wh/l (6680 Wh/l theoretical)
- **Caveat: Pressure Vessel structure mass held constant at this time**

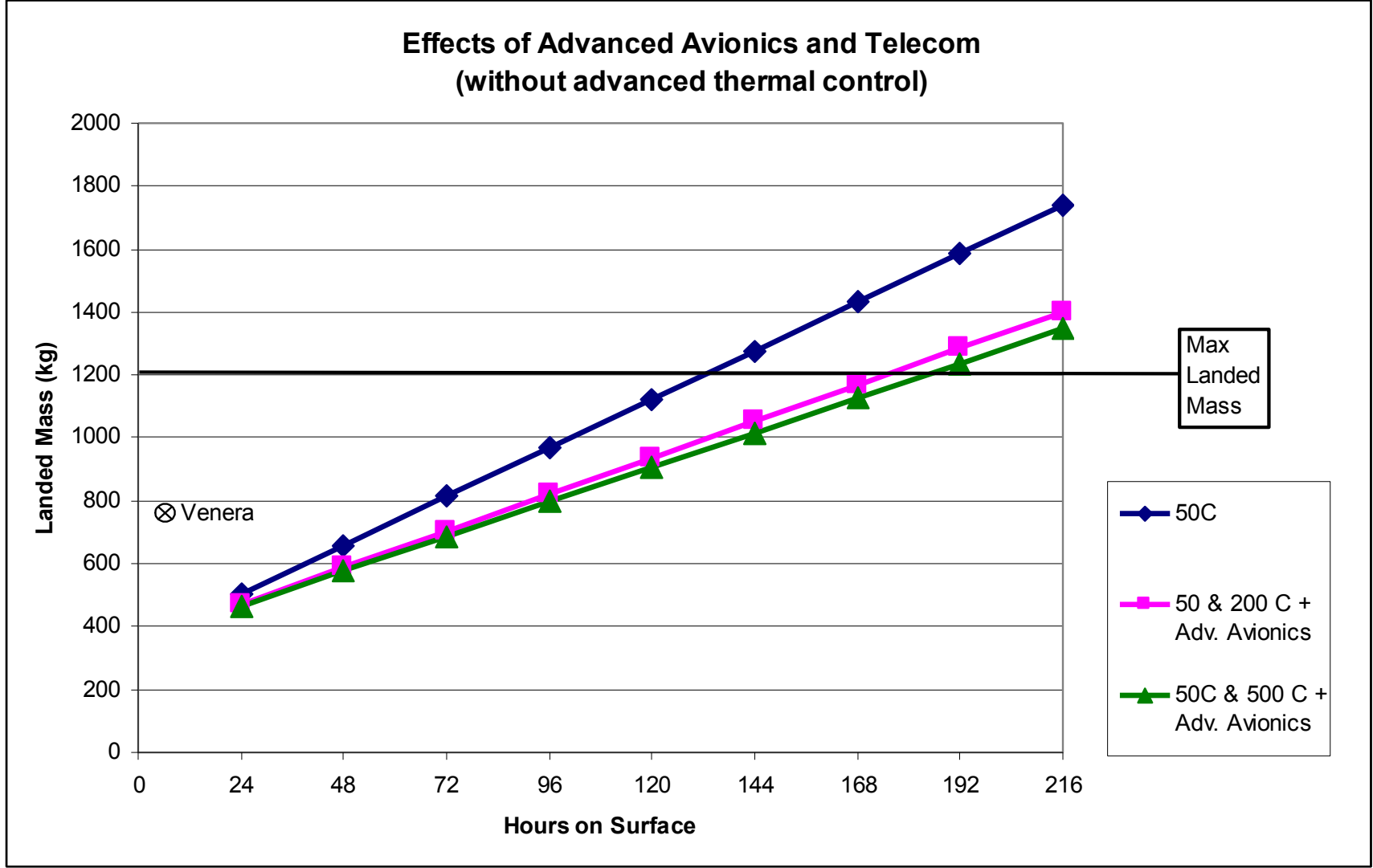


# **Evaluation of State of the Art HT Candidates**

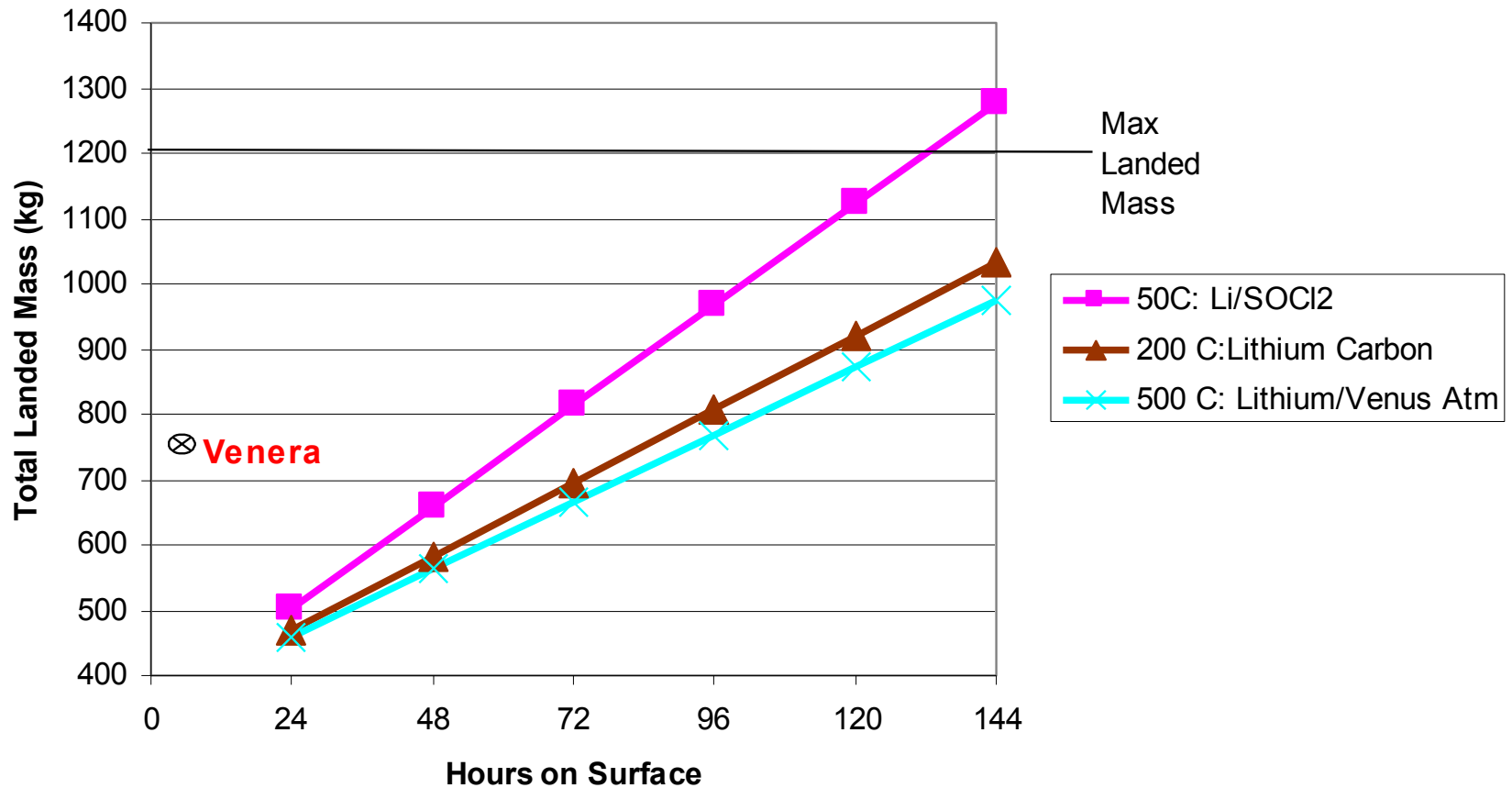
- **While state of the art high temperature (200 C) avionics provide some benefit, their increased power requirements make them less effective (in terms of total mass savings) than they would be if their power consumption was closer to that of their 50 C equivalent.**
  - **Basically the increased battery mass requirement almost offsets the savings in thermal mass.**
- **Current high temperature batteries have only ~ 60% of the specific power of the best 50 C batteries and are almost an order of magnitude more bulky, making them unattractive for any mission that requires a fair amount of power.**
  - **This may change for seismometer applications, where the power levels may be much smaller than those assumed for this study.**

## Effects of Advanced Thermal Control Materials

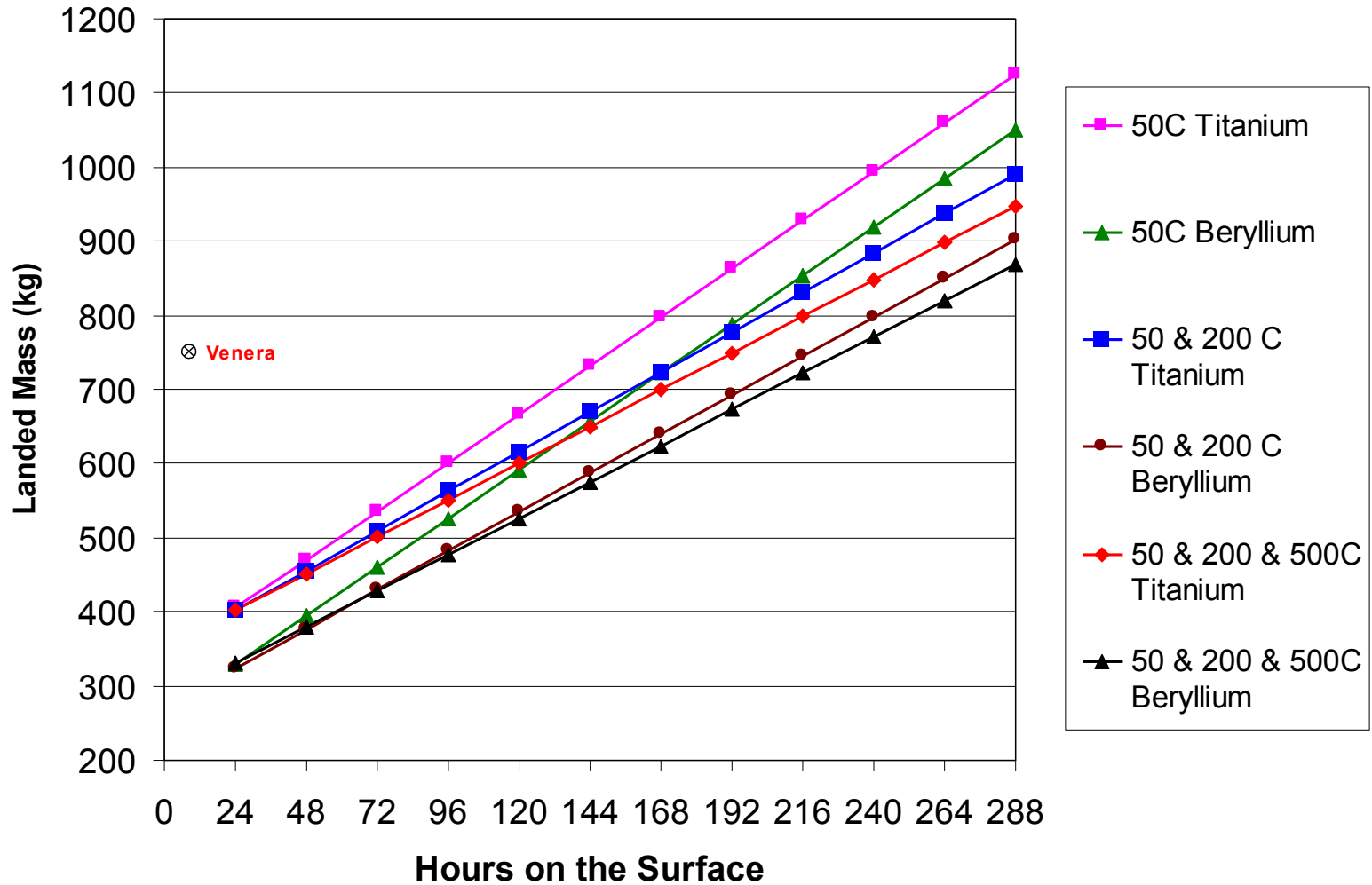


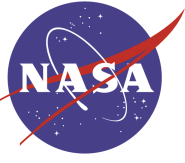


## Effect of Advanced Energy Storage (without advanced thermal control)



## Titanium vs. Beryllium with Advance Thermal and Avionics





# Final Conclusions

- **Current high temperature (200 C) components have higher power requirements than 50 C**
  - Increased power usage increases battery mass, off-setting savings in thermal mass for 200 C configuration using SOTA components.
- **Advanced thermal materials make a substantial improvement to mission life (possibly weeks), regardless of the configuration.**
- **Advanced 200 C avionics and telecom components provide noticeable benefit (possibly days), and 500 C components provide some additional benefit (hours)**
  - The benefits of 500 C components are offset by their greater power consumption.
- **Advanced high temperature batteries provide some benefit (hours to days) but their chief benefit may be in allowing for a reduction in the size of the temperature controlled pressure vessel.**
- **Using Beryllium instead of Titanium provides some improvement (about a day) to any scenario.**
- **Addition of the effects of scaling the pressure vessel would tend to increase the slope of the curves and reduce the landed mass for short lived missions.**



# **Thanks to my colleagues**

- **Elizabeth Kolawa –Extreme Environments Lead**
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